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Design, Development and Evaluation of Lever type Maize Sheller

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An investigation was carried out to design, develop and evaluate the performance of manually operated Lever type Maize Sheller (LMS). It consisted of a handle, guiding rod, supporting rod, spring loaded ram, maize cob guiding cylinder, shelling blade, buffer, collection chamber, shutter and frame. Performance of developed LMS was statistically compared with Tubular Maize Sheller (TMS) in terms of throughput capacity, shelling capacity, shelling efficiency, unshelled seeds and damaged seeds percentage at different maize cob length. The overall throughput capacity and shelling capacity was found to be 44.63 kg cobs/h and 33.90 kg seeds/h with LMS which was almost 3 times more as compare to TMS. The overall shelling efficiency of 96.34% and 99.45% was observed with LMS and TMS respectively. The unshelled seeds of 3.66% with LMS and 0.55% with TMS were observed. The seed damage during operation with LMS was around 5%, while it was nil in case of TMS. The total savings on shelling hundred kg seeds with LMS was found as ₹ 202 and ₹ 424 on comparing with TMS and bare hand method of shelling respectively. The performance evaluation and economic analysis reveals that the adoption of developed Lever type Maize Sheller can be economical and technically feasible.

Keywords: Economic analysis, Seed damage, Shelling capacity, Shelling efficiency, Throughput capacity

Introduction

Maize (*Zea mays*) is an important food grain ranking just next to rice and wheat. In 2018, the total maize production of India was 27.82 million tonnes where as area under cultivation is about 9.2 million ha.[1] It contributed around 10% of total food grain production of country. Maize crop is harvested with 25–30% moisture during its physiological maturity. The cob is then dried followed by dehusking prior to shelling. Shelling of maize refers to freeing the kernels out of the maize cobs. The energy consumption for only shelling of maize cob was 16.49% of total operational energy used in rainfed cultivation of maize crop in India.[2] Manual methods of shelling involves beating the cobs with sticks, rubbing cobs on one another, on bricks, stone, by fingers or wire mesh by using iron cylinder. These activities are laborious and time consuming leading to reduced output.[3] Several studies were carried out to develop manually, electric power, or tractor operated shellers with throughput capacities of 0.1 to 0.45 tonnes/h.[3–6] However they are costly and only suitable for farmers with large land holdings. Moreover, available engine and electric motor operated maize sheller cannot be purchased by the small farmer for single purpose. In the country, about 80.3% of farmers come under marginal community and 36% under small community.[6] Considering the above facts proposed study was carried out to develop a manually operated lever type maize sheller to increase the maize shelling capacity and reduce the labour cost and drudgery of small farmers and entrepreneurs.

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Materials and Methods

The proposed manually operated lever type maize sheller (LMS) was designed and fabricated in research workshop and performance evaluation was carried out in seeding and planting laboratory of ICAR-Central Institute of Agricultural Engineering, Bhopal.

Measurement of Physical Parameters of Maize Cob

Physical properties of maize cob play an important role in design and development of maize cob sheller. In order to design the sheller components, physical properties of maize cobs *viz*. moisture content, largest and smallest diameter, length and weight were measured.[5,7] Moisture content affects other properties of biological material.[8] Three samples of 100 g weight were used to measure the seed moisture content on wet basis (w.b.). ASAE standard oven method No. 352.2 was used to dry three random samples of each type of seed using hot air oven at 105°C temperature for 24 hours.[9] The diameter of maize cob generally decreased lengthwise. A random sample of 30 cobs was used to determine the dimensional properties. The largest and smallest diameters as well as length were measured by vernier calliper. The largest diameter obtained at the base of cob while smallest diameter at apex of the cob excluding the portion without kernels (Fig. 1(a)). The largest diameter was used to decide the diameter of cob guiding cylinder and smallest diameter for fixing the shelling blade diameter. As during the operation cobs were shelled length wise, so for the performance evaluation the cobs were classified into three groups according to their length. The capacities of sheller were defined in terms of material input. Hence, weight was recorded for three random samples of having ten cobs each by using a weighing balance to workout throughput capacity or material input per unit time. Three random samples of ten un-shelled cobs were collected and weighed. After shelling manually, the kernels were weighed and subtracted from the total weight, to get pith weight. The relation gave the weight proportion of seeds and pith into the cobs. The observed physical parameters are given in Table 1.

Design Consideration of Lever Type Maize Sheller (LMS)

The CAD drawing of LMS is shown in Fig. 2(a), while Fig. 2(b) shows the fabricated model of LMS. Creo Pro-Element software was used to develop CAD model of LMS. The second class lever mechanism was used as working principle of machine. Sheller handle made up of hollow pipe (MS) of 25 mm diameter to use as effort arm while guiding rod applied the load.[10] The handle length was kept as 1000 mm to take a mechanical advantage through travel of 700 mm from upper most position to lower most position. The supporting rod was acted as fulcrum, made of MS solid of 25 mm diameter fixed on base frame in a bush. The provision was made on support rod to adjust height of lever mechanism. Spring loaded ram was used to shell the cob by pushing it through stainless steel shelling blade with circular section of 30 mm diameter. Ram was made into two parts; solid piston of 27 mm diameter was bolted rigidly to the bottom portion of guiding rod which push cob deep in shelling blade while a spring-loaded inverted funnel shaped cover was provided to align the cob. The cob guiding cylinder was made of MS pipe of 55 mm diameter and 150 mm height after considering the cob of largest size. A gap of 50 mm was kept between lower edge of guiding pipe and shelling blade to make free fall of grains in the collection chamber. Barrier sheet was provided to prevent grain bouncing during the operation. At the bottom of storage, a sliding gate was provided to eject the grains. This whole shelling unit was fixed on

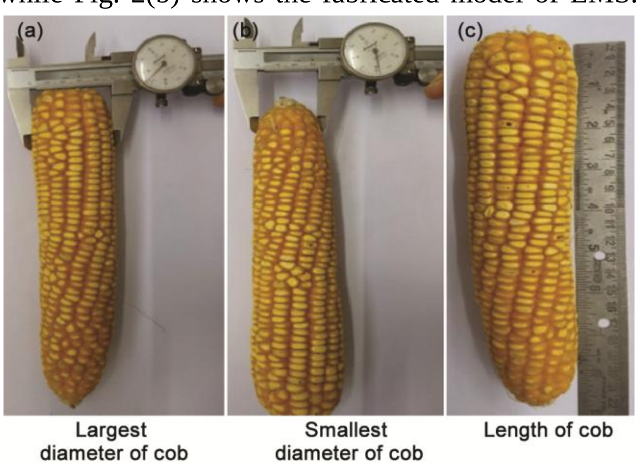

Fig. 1 — Determination of physical properties of maize cob

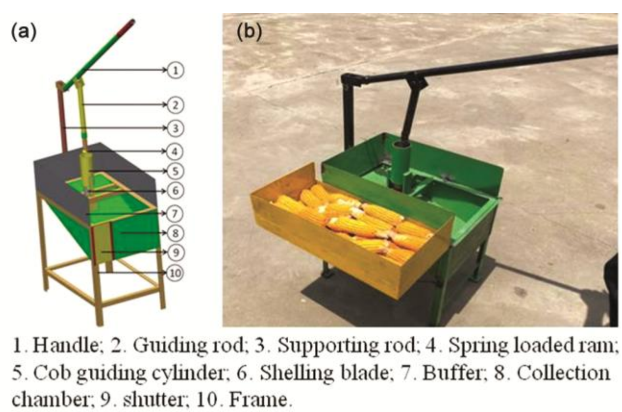

Fig. 2 — (a) CAD model, (b) Developed prototype of manually operated lever type maize sheller

Table 1 — Physical properties of maize cob

S. No.	Parameter	Minimum	Maximum	Mean ± S.D.
1.	Moisture content %, (w.b.)	8.89	8.93	8.91 ± 0.02
2.	Largest Diameter, mm	33	50	40.44 ± 5.81
3.	Smallest Diameter, mm	25	35	30.22 ± 3.11
4.	Length of cob, mm	105	210	152 ± 34.29
5.	Weight of cob, g	58.01	246.05	129.29 ± 60.94
6.	Seed to pith ratio	4.56	7.93	6.01 ± 1.07

frame of height of 500 mm. The total weight of LMS was found to be 22 kg.

Comparative Evaluation of LMS with TMS

The comparative evaluation of LMS with CIAE tubular maize sheller (TMS) was carried out considering following parameters. The harvested cobs of different sizes were categorised into three groups based on their length (less than 130 mm, 130 to 170 mm and more than 170 mm). The performance parameters *viz.* throughput capacity, shelling capacity, shelling efficiency, percent unshelled and seed damage were recorded for both type of shellers. The formulae of performance parameters used are as follows.[4,7]

$$\text{Throughput capacity (TC)}, \frac{\text{kg}}{\text{h}} = \frac{\text{Weight of cobs fed (kg)}}{\text{Time (h)}}$$

$$\text{Shelling capacity (SC)}, \frac{\text{kg}}{\text{h}} = \frac{\text{Weight of shelled seeds (kg)}}{\text{Time (h)}}$$

$$\text{Shelling efficiency } (\eta_s), \% = \frac{\text{Weight of seeds seperated (kg)}}{\text{Weight of seeds seperated (kg)} + \text{Weight of seeds unshelled (kg)}} \times 100$$

$$\text{Unshelled seeds } (\eta_u), \% = \frac{\text{Weight of seeds unshelled (kg)}}{\text{Weight of seeds seperated (kg)} + \text{Weight of seeds unshelled (kg)}} \times 100$$

$$\text{Damaged seed } (\eta_d), \% = \frac{\text{Weight of damaged seeds in 100 g sample of shelled seeds (g)}}{100} \times 100$$

Statistical analysis

SAS 9.3 software was used for analysis to find the significance of the parameters over shelling methods. Total of 18 numbers of experiments were carried out as two types of sheller were used for three cob lengths. Split-plot experiment was used for analysis to observe the effect of sheller type on maize shelling.

Cost Economics

Comparative economic analysis of developed lever type maize sheller was made with tubular maize sheller and bare hand shelling method. The fixed and variable cost of machine was derived by using straight line method. Considering tubular maize sheller and bare hand shelling method as base, average annual net profit and payback period were derived for the machine to shell 100 kg seeds using following equations.[10]

$$N = T_c - M_c$$

$$P = \frac{I}{s \times c}$$

where,
N = Average annual net profit, ₹
T_c = Cost by traditional method for machine per hour output, ₹
M_c = hourly cost of operation of machine, ₹
P = payback period, h
I = Initial cost, ₹
s = savings, units
c = capacity per hour, units

Results and Discussion

The result of comparative study of developed lever type maize sheller and CIAE tubular type maize sheller was given as follows.

Throughput Capacity

The F value of throughput capacity is as given in Table 2 shows that model (F = 826.82) was found significant at 1% level of significance with a good coefficient of determination (R^2 = 0.99) and coefficient of variance (CV = 2.97). The graphical representation of effect of independent parameter on throughput capacity is given in Fig. 3. It can be seen that the effect of replication was non-significant while the individual and interaction effect of cob length and shelling method was significant on throughput capacity. Least significant difference (LSD) comparisons indicate that levels of independent parameters were also affected significantly. The average throughput capacity of LMS for small, medium and large sized cobs was observed to be 22.31, 46.16 and 65.43 kg cobs/h which was 78, 221 and 310 percent higher than that of TMS respectively. The result shown in Table 3 depict that throughput capacity increases significantly as the length of cobs increased irrespective to type of sheller used probably this is due to more number of small cobs per kg which takes more time for handling it. The lowest throughput capacity (12.48 kg/h) was found at small cob size with TMS whereas, LMS recorded highest throughput capacity of 65.43 kg/h at large cob size. It can also be depicted from Table 3 that overall average throughput capacity of LMS (44.63 kg/h) which was 3.13 times more than TMS.

Shelling Capacity

The statistical analysis given in Table 2 depict that the individual and interaction effect of length of cob and shelling method on shelling capacity was significant whereas value of R^2 (0.99) and CV (2.15) shows the

Table 2 — ANOVA for effect of independent parameters on performance parameters

Source	DF	F Value			
		Throughput capacity	Shelling capacity	Shelling efficiency and percent unshelled seed	Percent seed damage
Model	11	826.82**	1494.14**	46.43**	76.76**
Error	6	—	—	—	—
Corrected Total	17	—	—	—	—
Replication (R)	2	1.24^{NS}	2.10^{NS}	0.02^{NS}	1.05^{NS}
Length of cobs (LC)	2	1639.82**	610.46**	33.82**	7.45*
R x LC	4	0.65^{NS}	3.41^{NS}	2.24^{NS}	0.68^{NS}
Type of Sheller (TS)	1	5415.14**	9242.00**	284.09**	809.28**
LC × TS	2	772.20**	1504.59**	33.13**	7.27*
LSD_{LC}	—	1.13 kg cobs/	1.45 kg seeds/	0.94%	0.59%
LSD_{TS}		h 1.01 kg cobs/h.	h 0.57 kg seeds/h.	0.45%.	0.43%.
R^2	—	0.99	0.99	0.99,	0.99
CV	—	2.97	2.15	0.40 / 18.63	14.91
RMSE		0.88	0.49	0.39	0.37

R^2 = coefficient of determination, CV = coefficient of variance, RMSE = root mean square error, * = significant at 5% level of significance ** = significant at 1% level of significance, NS = non-significant

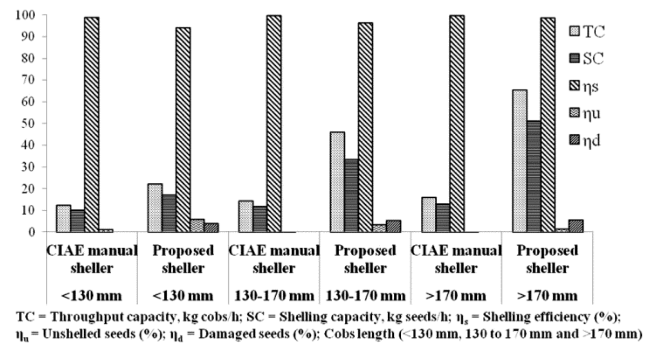

Fig. 3 — Effect of sheller type and cob length on performance parameters

good uniformity in data. The shelling capacity of LMS for small, medium and large sized cobs was recorded to be 17.22, 33.46 and 51.02 kg seeds per hour which was 68, 181 and 293 percent more than the capacity recorded for TMS respectively. From the Table 3, it was observed that shelling capacity increases significantly with cob length in both method of shelling may be due to the same reason as given for throughput capacity. The overall average shelling capacity of 11.67 kg/h and 33.90 kg/h was observed with TMS and LMS respectively. Similar to throughput capacity, overall average of shelling capacity of TMS is also very less (2.9 times) compared to LMS values. Further, individual highest shelling capacity of 51.02 kg/h and 12.95 kg/h was recorded for LMS and TMS respectively at large cob size.

Shelling Efficiency and Percent Unshelled Seed

F value given in Table 2 for effect of cob length and shelling method on shelling efficiency and percentage unshelled seeds indicates that both parameters were affected significantly at 1% level of significance whereas effect of interaction was also found significant. LSD showed that no level of cob length and shelling method were at par with each other. The shelling efficiency of LMS estimated to be 93.97% for small cobs, 96.48% for medium cobs and 98.58% for large cobs which was just lesser than the efficiency recorded for TMS by 4.94, 3.31 and 1.26% respectively (Table 3). Comparatively higher percentage of efficiency recorded in TMS may be due to slower speed of work. Further, percentage unshelled seeds with TMS also lower than the LMS for all size of cobs (Table 3). Moreover, the shelling efficiency of developed sheller was also highest with cobs of largest length with an overall average value of 96.34% which was only 3.12% less than shelling efficiency of TMS. The highest average of unshelled seeds was observed in small size cobs *i.e.* 1.09% and 6.03% for TMS and LMS respectively. Whereas, lowest percentage of unshelled seeds for LMS (1.42%) and TMS (0.16%) were found at largest cob size.

Percent Seed Damage

The F value of percentage damaged seeds (%) as given in Table 2 indicate that model was highly significant at 1% level of significance. Length of cobs affected significantly at 5% level of significance while sheller type affected at 1% level of significance. The interaction of effect of independent parameters was however, non-significant at 1% level of significance. LSD showed that level 2 and 3 of cob length were at par with each other but level 1 was

Table 3 — Comparative evaluation of CIAE Manual sheller (TMS) with proposed lever type maize sheller (LMS)

Parameters	Sheller type / Range of cob lengths	CIAE Manual Shelter (TMS) Avg.	Overall Mean	SD	Proposed Sheller (LMS) Avg.	Overall Mean	SD
TC	Small (<130 mm)	12.48	14.26	1.70	22.31	44.63	18.72
	Medium (130-170 mm)	14.35			46.16		
	Large (>170 mm)	15.95			65.43		
SC	Small (<130 mm)	10.20	11.67	1.38	17.22	33.90	14.65
	Medium (130-170 mm)	11.87			33.46		
	Large (>170 mm)	12.95			51.02		
η_s	Small (<130 mm)	98.91	99.45	0.46	93.97	96.34	2.06
	Medium (130-170 mm)	99.61			96.48		
	Large (>170 mm)	99.84			98.58		
η_u	Small (<130 mm)	1.09	0.55	0.46	6.03	3.66	2.06
	Medium (130-170 mm)	0.39			3.52		
	Large (>170 mm)	0.16			1.42		
η_d	Small (<130 mm)	0	0	0	4.06	5.01	0.85
	Medium (130-170 mm)	0			5.42		
	Large (>170 mm)	0			5.54		

TC = Throughput capacity, kg cobs/h; SC = Shelling capacity, kg seeds/h; η_s = Shelling efficiency, %; η_u = Unshelled seeds, %; η_d = Damaged seeds, %; Avg = Average value for particular group; Overall Mean = Overall average value; SD = Standard deviation.

significantly different. Pair-wise comparison for sheller type showed that all levels are significantly different. For TMS, no damaged seeds were observed. This may be due to the slower speed of work. While in case LMS, percent damaged seeds were recorded as 4.06% for small cobs, 5.42% for medium cobs and 5.54 for large sized cobs. The highest seed damage percentage was observed with large cob size but there is slight difference between percent seed damage (0.12%) obtained from medium and large cob size. Moreover, the overall average seed damage of 5.01% was observed with LMS.

Cost Economics

Comparative economic analysis of developed lever type maize sheller was made with tubular maize sheller and bare hand shelling method as base. The cost estimation and payback period, which are most important economic aspects, were recorded to decide economic benefit of developed prototype. The material and fabrication cost of ₹ 1500 was recorded for developed machine. Besides, one labour is required to operate the machine. As per calculation, the total of fixed and variable cost of ₹ 40.28 per hour was recorded for LMS. The cost of shelling was calculated by considering daily wages for 8 hours and shelling capacity on per hour basis. From the calculation, it was found that the cost of shelling of 100 kg seeds incurred for bare hand method, TMS and LMS was ₹ 543.5, ₹ 321 and ₹ 119, respectively. On comparing LMS with bare hand method, the total savings of ₹ 424 was found on shelling hundred kg seeds with an average hourly net profit of ₹ 143.79. Moreover, the payback period of machine was 10 hours of shelling operation. Similarly, on comparing LMS with TMS, the total savings of ₹ 202 was found on shelling 100 kg seed with an average hourly net profit of ₹ 72. The payback period of the developed machine was 21 hours of shelling operation. Hence, this cost analysis shows that the use of LMS is economical and technically feasible.

Conclusions

The present study shows that developed Lever type Maize Sheller gives higher throughput and shelling capacity as compare to tubular type maize sheller which can save the labour cost and time. Moreover, low cost of equipment, great saving on shelling cost and acceptable value of performance parameter like shelling efficiency, unshelled seed and percent seed damage making this prototype more suitable and economically viable for maize shelling. Thus, adoption of this developed technology can help farmers and small entrepreneurs to ease out maize shelling operation which can reduce drudgery and tediousness involved in it.

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